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FINAL REPORT

NUMERICAL AERODYNAMIC SIMULATION FACILITY

PRELIMINARY STUDY EXTENSION

February 1978

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EXECUTIVE SUMMARY

Prepared under Contract No. NAS2-9456 by
Burroughs Corporation
Paoli, Pa.

for

AMES RESEARCH CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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INTRODUCTION

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Burroughs Corporation is pleased to present this report which is the result of work carried on under an extension to contract No. NAS2-9456, a Preliminary Study for a Numerical Aerodynamic Simulation Facility. The primary objective of this extension is to produce an optimized functional design of key elements of the candidate facility defined in the Final Report[1] of the basic contract. This is accomplished by effort in the following tasks:

- To further develop, optimize and describe the functional description of the custom hardware
- To delineate trade-off areas between performance, reliability, availability, serviceability and programmability
- To develop metrics and models for validation of the candidate system's performance
- To conduct a functional simulation of the system design
- To perform a reliability analysis of the system design.
- To develop the software specifications to include a user level high level programming language, a correspondence between the programming language and instruction set and outline the operating system requirements.

The results of this effort are presented in five separate chapters in the report.

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[1] Burroughs Corporation, "Final Report, Numerical Aerodynamic Simulation Facility, Preliminary Study," Dec. 1977.

Chapter 2 - Functional Description includes a summary of the system parameters, block diagrams, descriptions, of the major elements and the instruction set with detailed timing.

Chapter 3 - Software Issues describes the extensions and restrictions on the FORTRAN language and compiler at the functional level. A discussion of converting statements is extended FORTRAN into machine language and a statement regarding the operating system.

Chapter 4 Simulations presents the models, metrics and methodology for conducting the simulation along with preliminary results.

Chapter 5, Reliability includes two sections. The first presents the results of an availability analysis of the systems and the second present further discussion of the error, detection, correction and control to be employed.

Chapter 6, Trade-offs delineates and discusses a large number of design and operating factors for which reasonable alternative exit.

While the information in this report is designed to stand alone it is also considered to be a supplement to the Final Report (Reference 1) of the basic NAS2-9456 contract where appropraite reference is made to this report rather than to unncessarily repeat previously reported information.

In addition, it should be pointed out that certain terminology used in the previous report have been revised. The new terms are:

- Flow Model Processor (FMP) - This is the portion of the system previously called the Navier-Stokes Solver (NSS)
- Processor Data Memory (PDM) was previously called Processing Element Memory (PEM)
- Processor Program Memory (PPM) was previously called Processing Element Program Memory (PEPM)
- Execution Unit (EU), the logic portion of the array processor, formerly called processing element (PE).

The following sections summarize the chapters in additional detail.

FUNCTIONAL DESIGN

The FMP is an array processor of 512 processors, a control unit, and 521 modules of extended memory, as described in Reference 1. The major additions found in Chapter two, to the description of reference 1, are first, the provision of SECDED, instead of parity-plus-retry, as the expected means of error control in the processors' memory; second, the addition of four on-line spare processors as definitely a part of the design (they are mentioned briefly as a possibility in reference 1); third, significant revisions and additions to the instruction set; fourth, the restriction of the extended memory instructions to fetching 512 words (one per processor) per instruction, (the earlier description had EM instructions fetching 512 $\times$ N words per instruction); and fifth, provision for special hardware for computing any floating-point variables that are not members of a vector.

Chapter two includes diagrams and figures of every element of the FMP.

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SOFTWARE

The software chapter covers the FORTRAN language, to a depth necessary to hover simple test cases, discusses hand compiling, and is charged with the task of reporting on progress in defining the operating system during this contract extension. Three and only three extensions are visualized for the initial FORTRAN language. First, the DOALL construct declares to the compiler that the iterations of a particular loop can be done in any sequence, or all in parallel, without affecting the result; second, declarations of several types of use of variables are used to allocate those variables among the different types of memory; third, certain system library functions are required, because of the parallel nature of the machine, that would not be required in serial FORTRAN. None of these library functions are required for the initial benchmarks.

The operating system is extensively described in reference 1. The level of detail in that document is such that the effort of the contract extension was spent more fruitfully on language definition, compiler considerations, and hand compilation procedures. Thus, the operating system discussion in reference 1 still stands as the best description so far produced of the operating system of the FMP. No attempt has been made to update that description for this report.

SIMULATION

Chapter four discusses the separation of the simulation effort into two levels, instruction and FMP level, and the system level. Metrics for each level are discussed. SUBROUTINE TURBDA has been selected as the metric for the simulation done in this extension. Reasons for that selection are given. The BOSS simulator, in which our simulation is being done, is described briefly in chapter four.

RELIABILITY

A detailed computer model for the reliability of the FMP was run. The results of this model bound the availability at 96 percent being the lower limit of availability using pessimistic assumptions, and better than 99 percent availability being achieved under the most optimistic assumptions. The use of spare processors with operating system automatic restart (assumed successful for some fraction of all attempts) produces a very significant improvement over the model that has no spare processors.

The reliability section also includes a discussion of the use of SECDED in all memory, of the process of "scrubbing" out the errors that spontaneously arise in CCD storage (DBM), and of other error control strategems that are used in the FMP.

TRADEOFFS

Chapter six discusses tradeoffs in many areas. These include ease of programming versus execution efficiency, where one wishes to have most of both, word and instruction formats, error control methods versus their cost in reduced throughput, several specific design issues, relative speeds of specific blocks of the system, alternate methods of supplying the floating-point scalar capability, and other topics, with a final section on the expansibility of both the specific FMP, once built, and the expansibility of the design from which it was built.